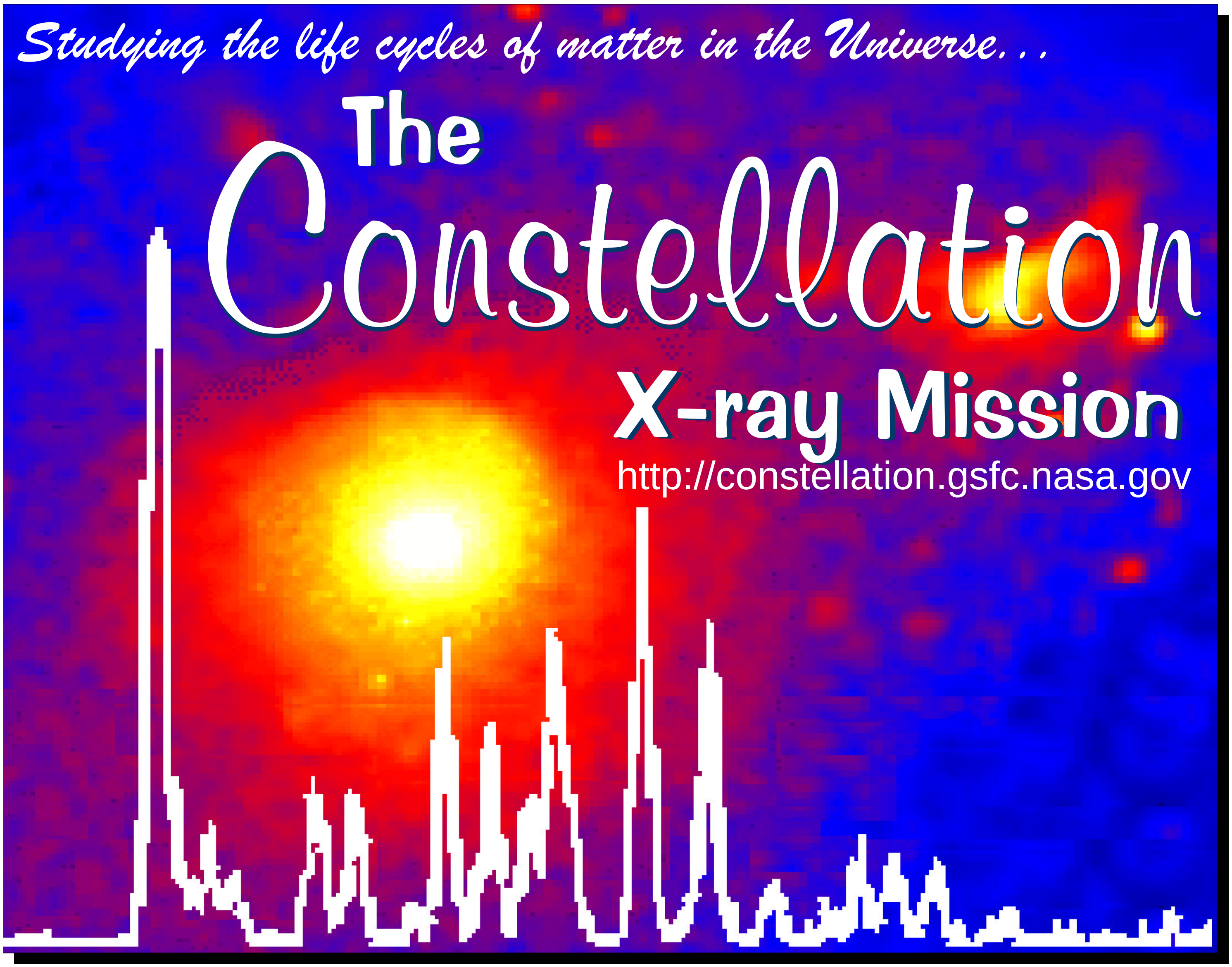
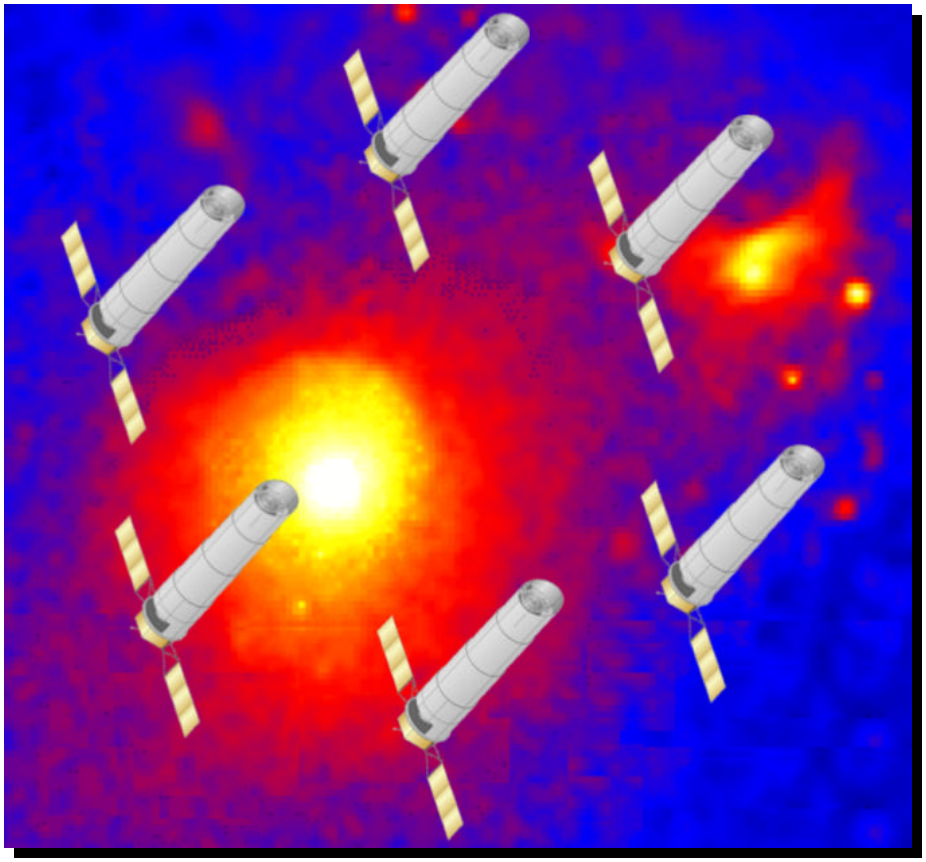
The Constellation X-ray Mission



The Constellation X-ray Mission

Studying the life cycles of matter in the Universe

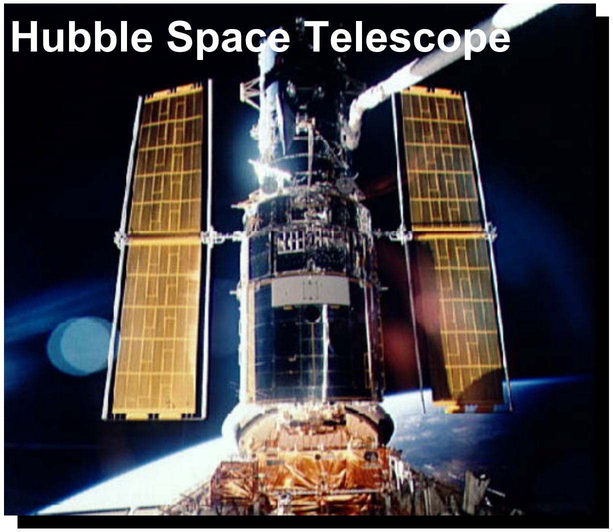


Constellation-X

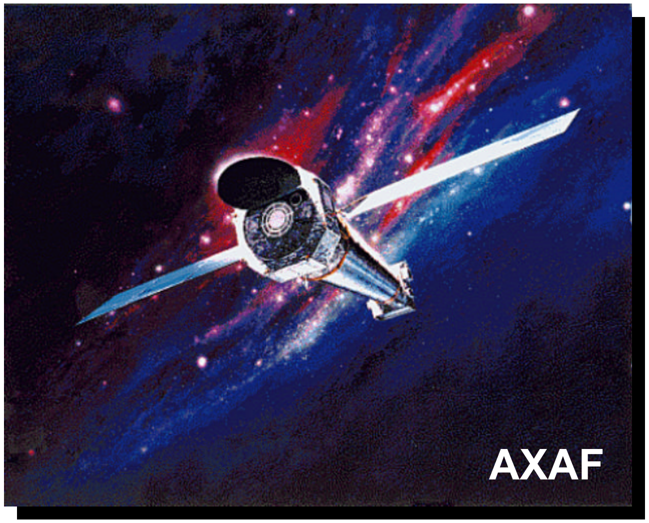
- Key scientific goals
  - Elemental abundances and enrichment processes throughout the Universe
  - Parameters of supermassive black holes
  - Plasma diagnostics from stars to clusters
- Mission parameters
  - Effective area: 15,000 cm^2 at 1 keV
    100 times AXAF and XMM for high resolution spectroscopy
  - Spectral resolving power: 3,000 at 6.4 keV
    5 times Astro-E calorimeter
  - Band pass: 0.25 to 40 keV
    100 times increased sensitivity at 40 keV

X-ray Equivalent of the Keck Telescope

Imaging



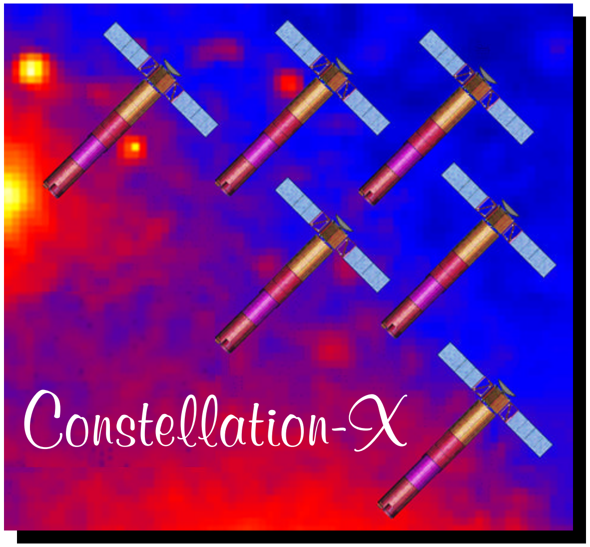
0.1 arc sec
40,000 cm^2



0.6 arc sec
1,000 cm^2
(100 cm^2)*

Spectroscopy

1 arc sec
780,000 cm^2



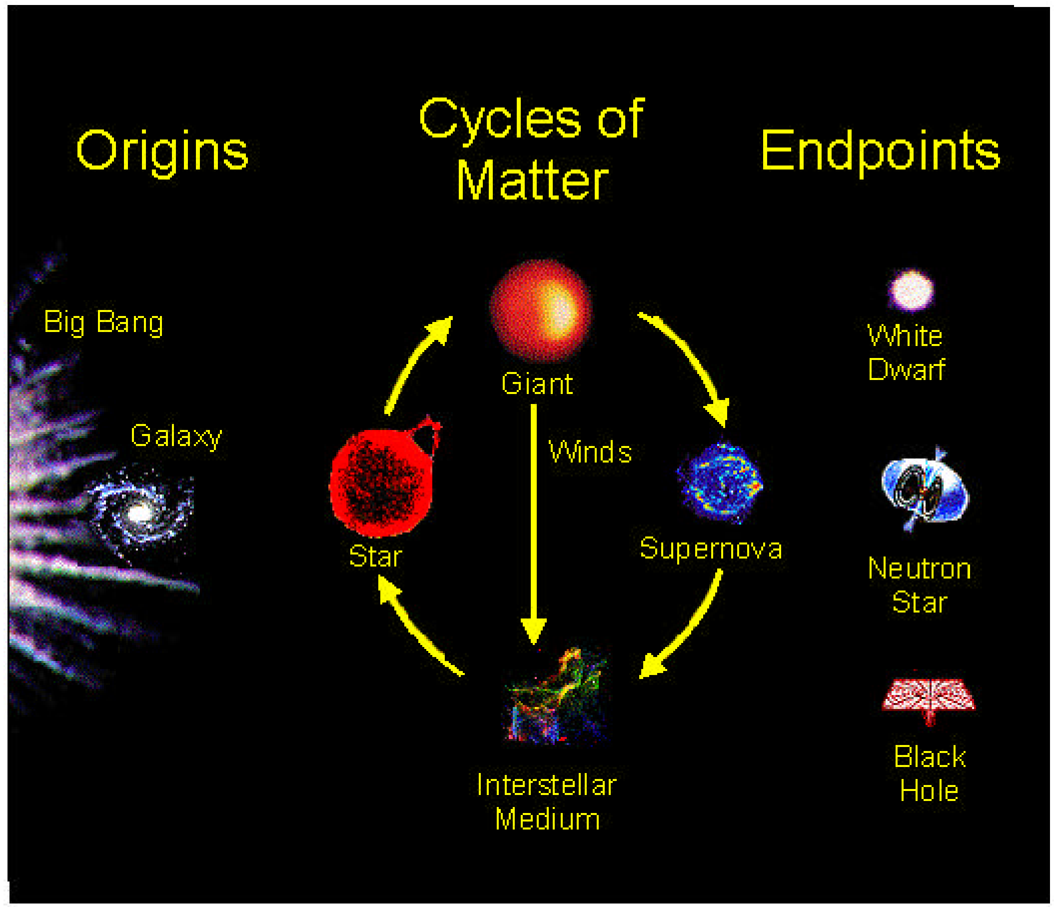
15 arc sec
30,000 cm^2
(15,000 cm^2)*

* effective area at the spectrometer

Studying the Life Cycles of Matter with the Constellation X-ray Mission

Obtain high quality X-ray spectra for all classes of X-ray sources over a wide range of luminosity and distance to determine:

- **the abundance of elements with atomic number between Carbon and Zinc (Z=6 to 30) using line to continuum ratios**
- **the ionization state, temperature, and density of the emission region using plasma diagnostics**
- **the underlying continuum process with a broad bandpass**
- **dynamics from line shifts and line broadening**



Constellation-X Requirements Flow Down

Science Goals

Elemental Abundances and Enrichment throughout the Universe

Parameters of Supermassive Black Holes

Plasma Diagnostics from Stars to Clusters

Measurement Capabilities

Minimum effective area: 15,000 cm^2 at 1 keV
6,000 cm^2 at 6.4 keV
1,500 cm^2 at 40 keV

Telescope angular resolution: 15" HPD from 0.25 to 10 keV
1' HPD above 10 keV

Minimum Diameter Field of View: 2.5 arcmin < 10 keV
8 arcmin > 10 keV

Minimum spectral resolving power ($E/\Delta E$): 300 from 0.25 to 6.0 keV
3000 at 6 keV
10 at 40 keV

Band Pass: 0.25 to 40 keV

Key Technologies

High Throughput Optics

- *Lightweight ó 250 kg*
- *Replicated shells and segments*

High Spectral Resolution

- *2 eV microcalorimeter arrays*
- *Coolers*
- *Lightweight gratings*
- *CCD arrays extending to 0.25 keV*

Broad Bandpass

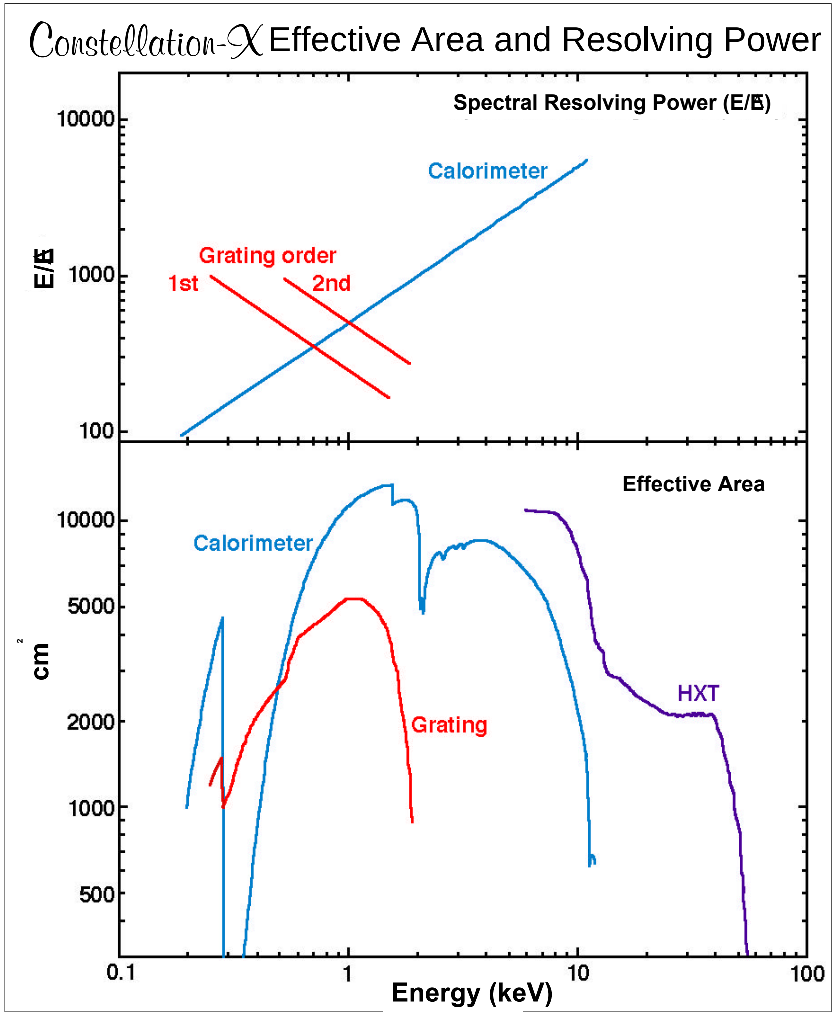
- *Multilayer optics*
- *CdZnTe detectors*

Top Level Mission Performance Requirements

- The effective area specified assumes a high (> 95%) viewing efficiency per orbit during the life of the mission.
- For orbits with lower viewing efficiencies, the total mission effective area ***or*** the duration of mission must increase proportionately to the loss in viewing efficiency.
- During on-orbit operations, the total mission effective area must be pointed toward the same target at the same time ($\pm$ 5 minutes).
- Redundancy/reliability such that no one failure can result in loss of more than 30% of the mission science
- Mission life
  - three years minimum at full performance
  - five years goal

Constellation-X Science Payload

Two coaligned telescope systems cover the 0.25-40 keV band.



A spectroscopy X-ray telescope (SXT) from 0.25 to 10.0 keV

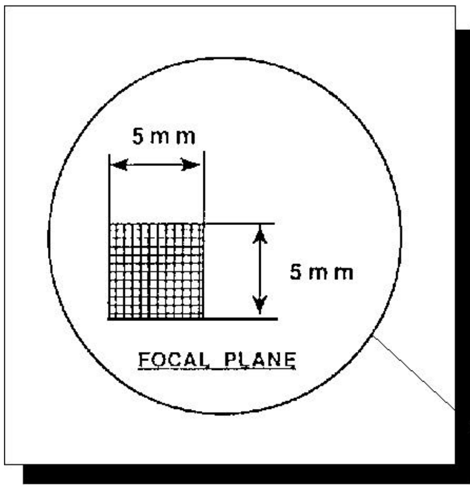
- an array of microcalorimeters with 2 eV resolution.
- a reflection grating/CCD to maintain resolution > 300 below 1 keV

A hard X-ray telescope (HXT) from 10 to 40 keV

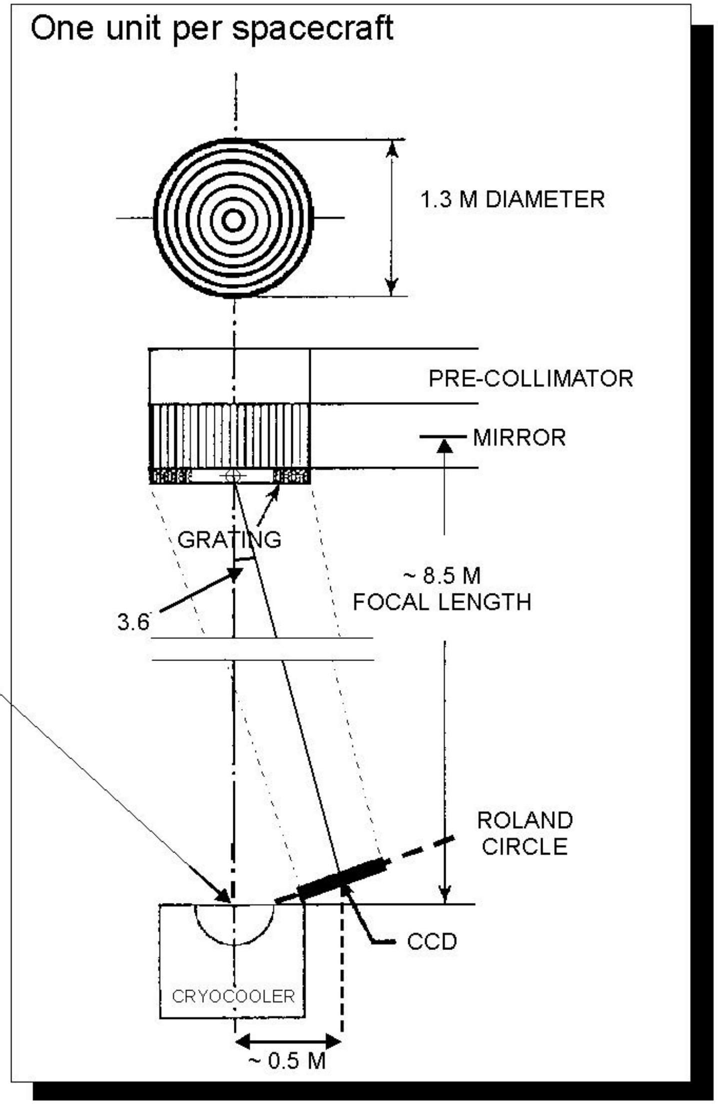
- grazing incidence optics
- an energy resolution ~1 keV, sufficient to measure the continuum

Constellation-X Instrumentation

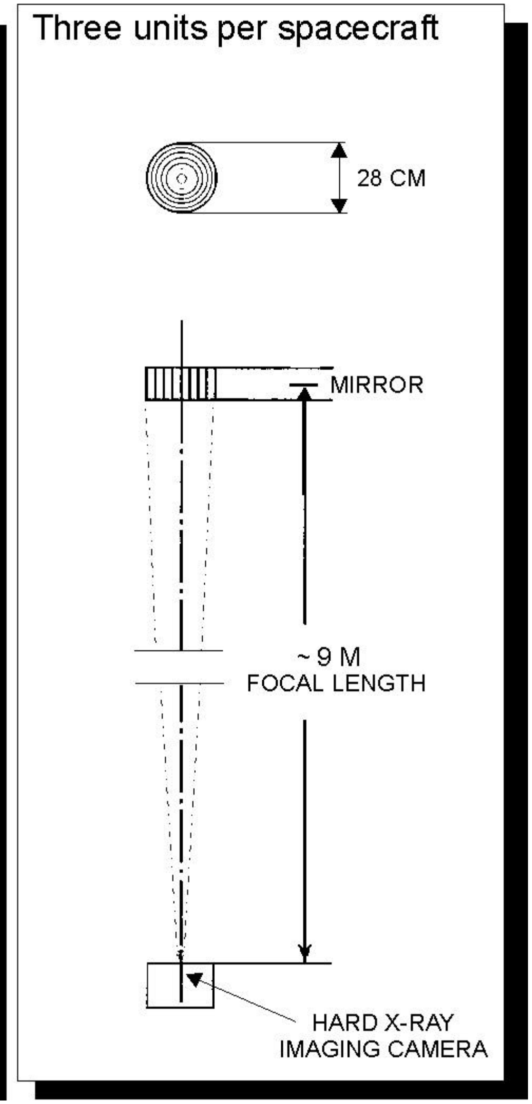
Calorimeter Array



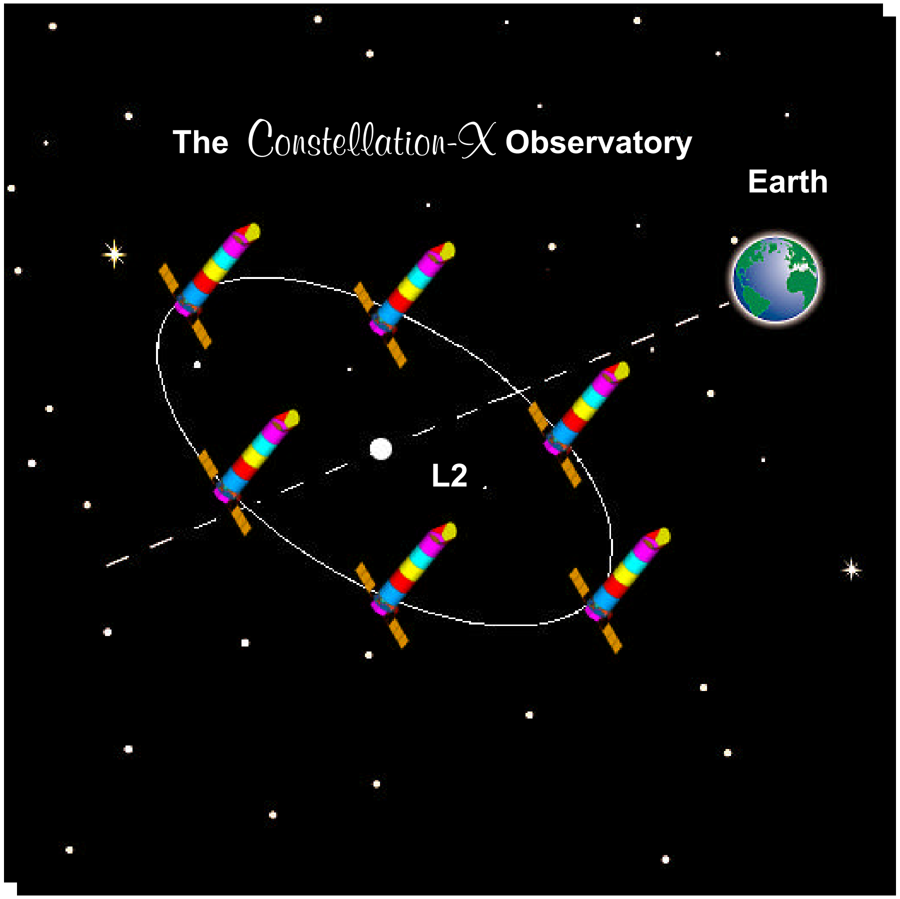
Spectroscopy X-ray Telescope



Hard X-ray Telescope



The Constellation-X Multi-satellite Approach to Large Collecting Area



To achieve 15,000 cm^2 effective area on a single satellite requires a Titan-class launch.

An alternative low-risk approach to achieve large X-ray collecting area is to utilize a constellation of six identical low-cost Delta-class satellites.

Launch intervals of three months.

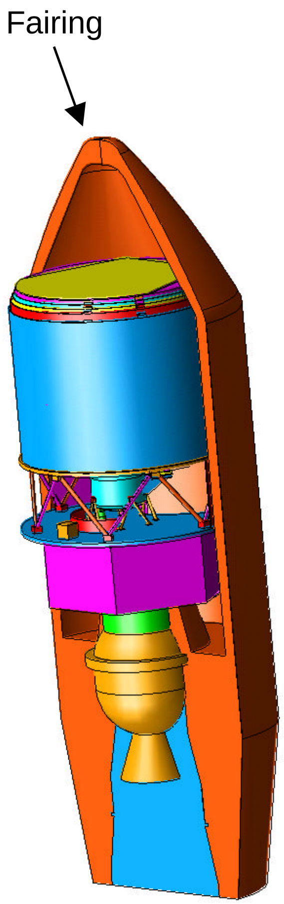
Facilitate simultaneous viewing and high efficiency by using libration point orbit.

- Low-Earth orbit mission requires increased collecting area or mission life.

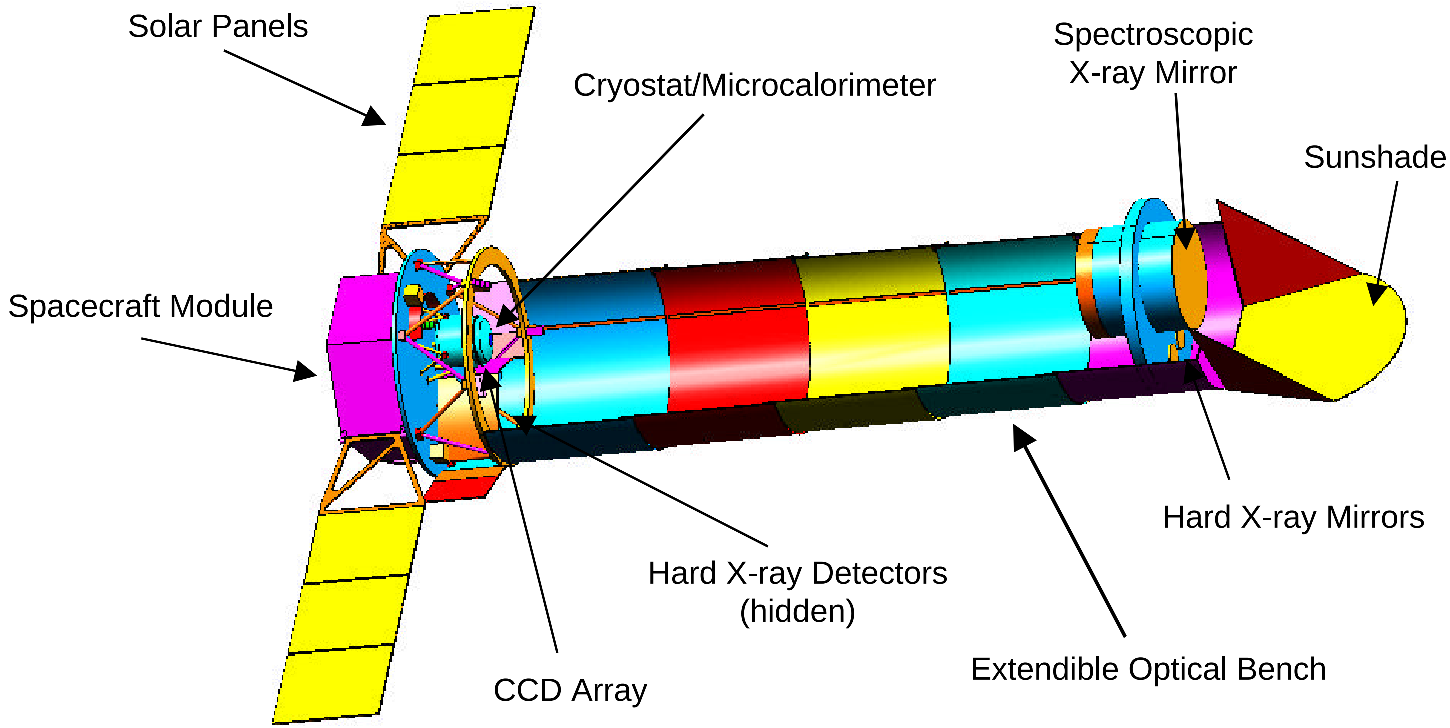
Spacecraft design lifetime is three years

- consumables targeted for a five-year mission

Constellation-X Reference Design



Stowed

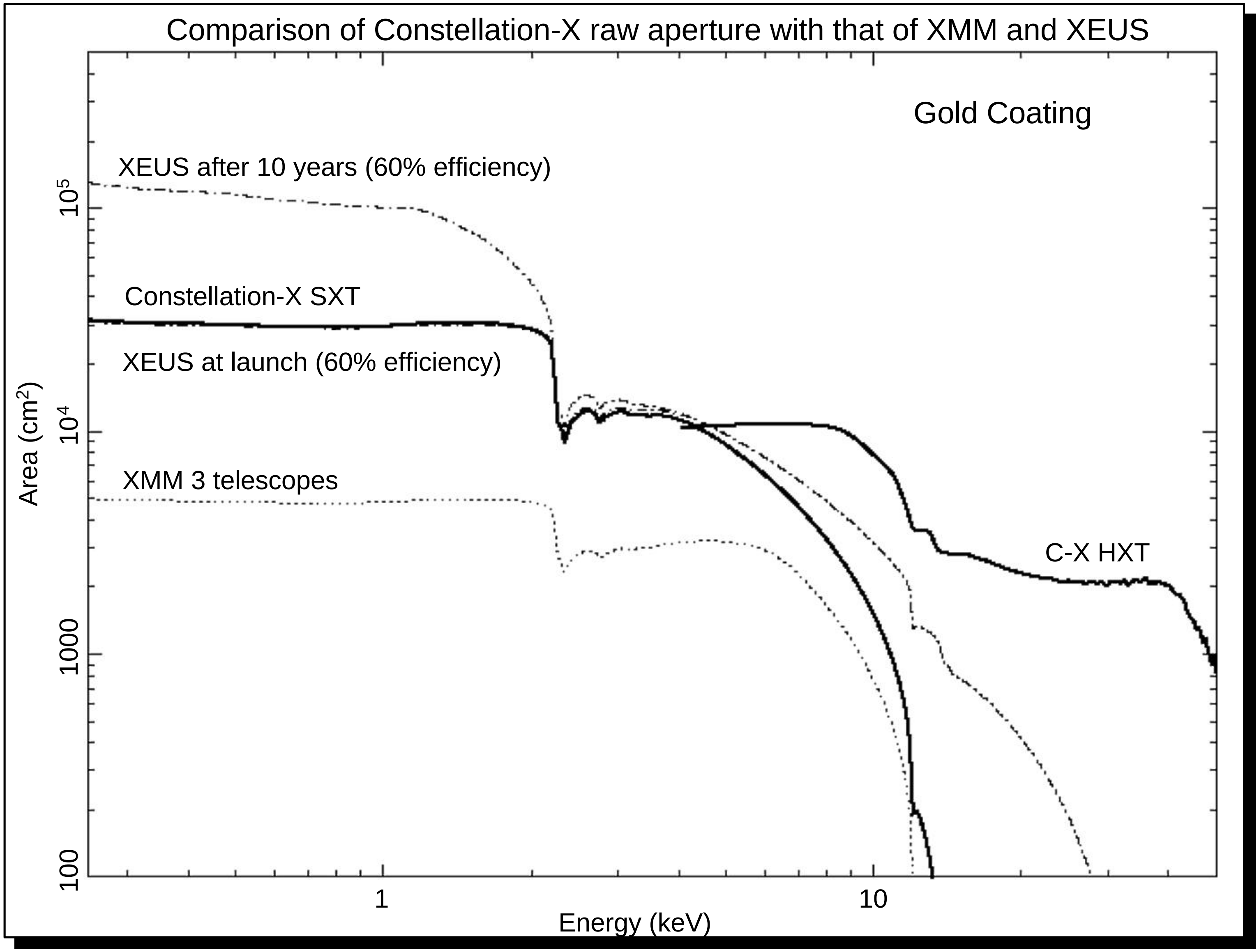


Deployed

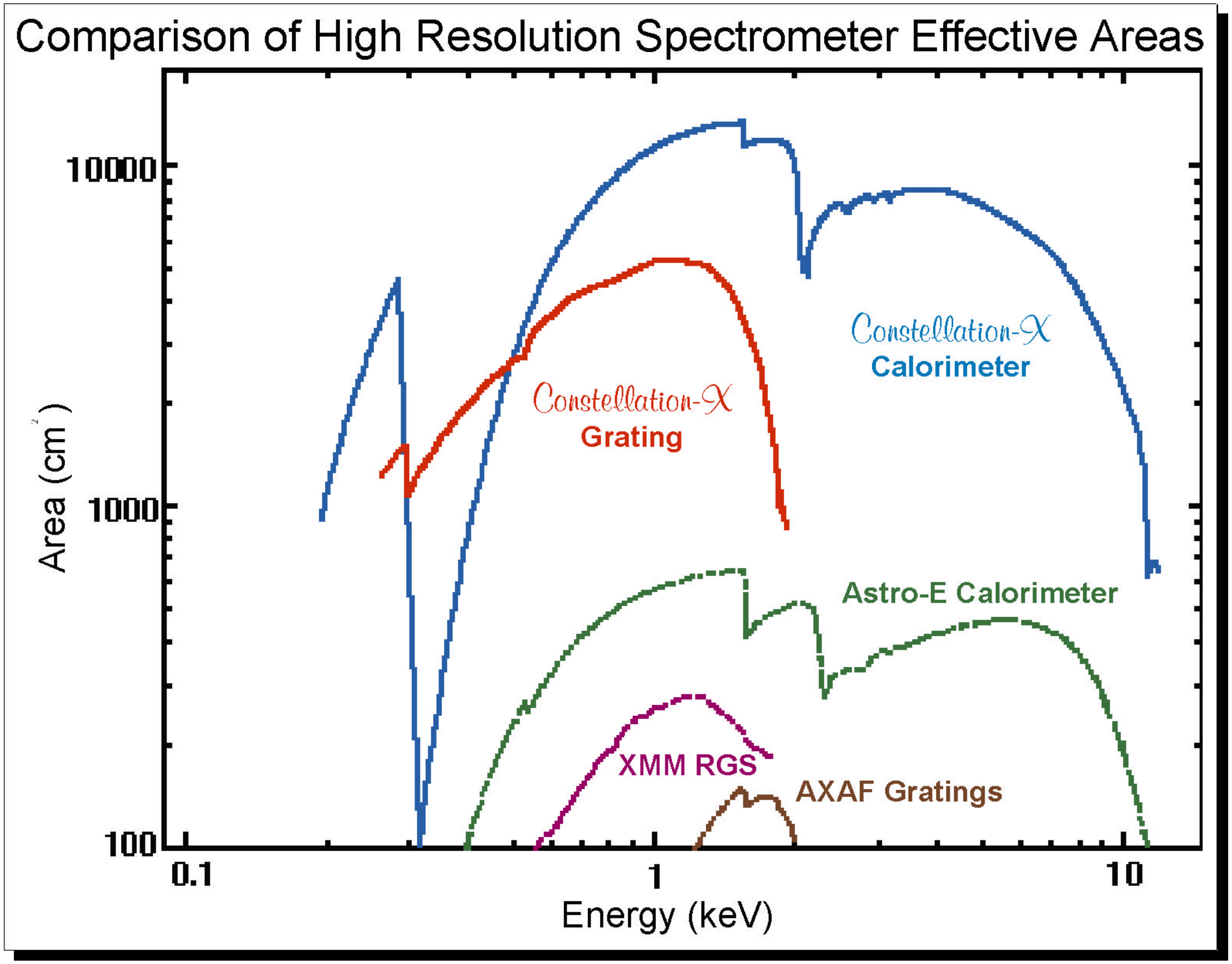
Comparison of X-ray Observatories
Raw Collecting Power

	AXAF	XMM	Constellation-X	XEUS
Focal Length (m):	10	7.5	8.5	25
Diameter (m)	1.2	0.7	1.3	10
Number of Telescopes:	1	3	6	1
Angular Resolution (HEW) (arc sec):	0.5	15	15	5
Collection Area (cm^2):				
1 keV	800	5,000	30,000	100,000
6.4 keV	300	2,500	6,000	8,000
40 keV	-	-	1,500	-
Spectrometer 1keV area	100	300	15,000	50,000
Observing Efficiency:	95%	95%	95%	60%
Effective 1 keV area	95	285	14,250	30,000

X-ray Observatories Raw Aperture Comparison



Constellation-X Advanced Capabilities
I. High Throughput

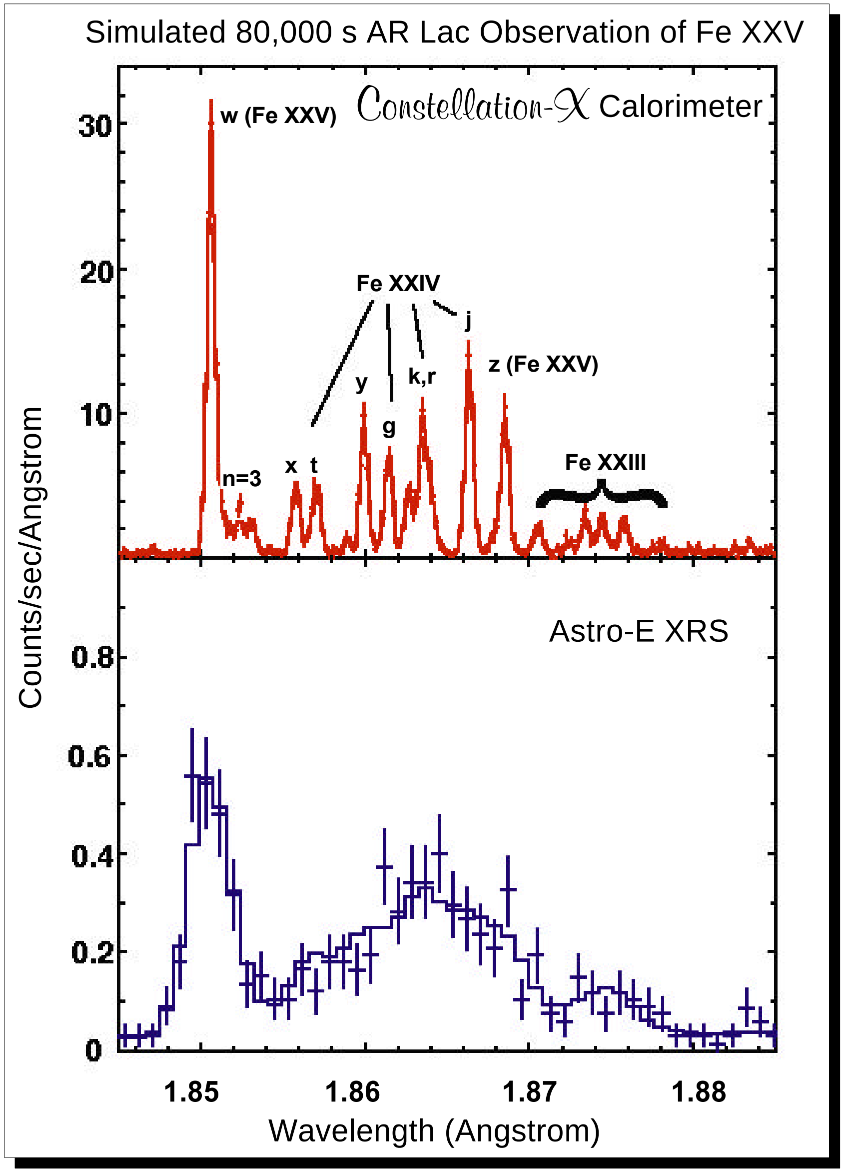


A 20-100 fold gain in effective area for high resolution X-ray spectroscopy

High throughput optics plus high quantum efficiency calorimeters

Lightweight reflection gratings maintain resolution and coverage at low energies (< 1 keV)

Constellation-X Advanced Capabilities
II. High Spectral Resolution



The Next Generation Microcalorimeter Array

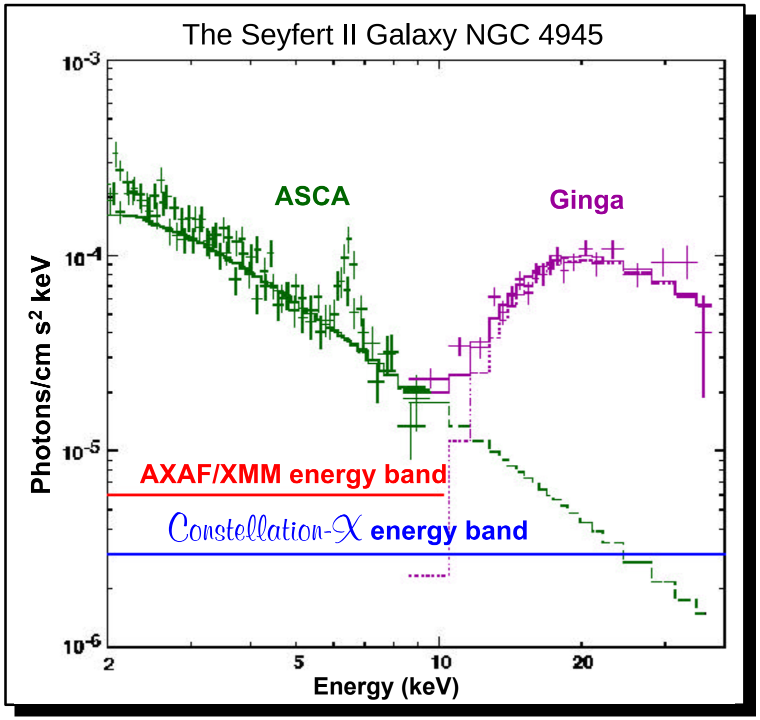
High quantum efficiency with the capability to map extended sources

- A factor of 5 improvement (to 2 eV) in spectral resolution
- Successor to the calorimeter to be flown on Astro-E (2000-2002)
- At Iron K, 2 eV resolution gives a velocity diagnostic of 10 km/s

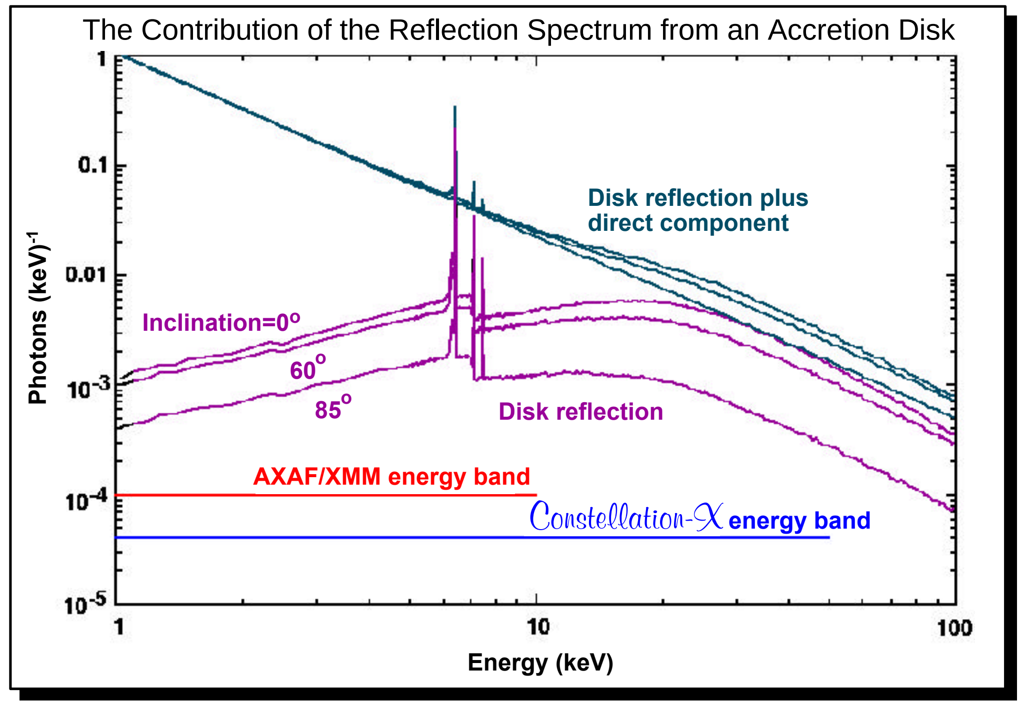
Constellation-X Advanced Capability
III. Hard X-ray

The hard X-ray band is crucial to determine the underlying continuum

Planned missions (AXAF, AMM, Spectrum XG, and Astro-E) have limited or no sensitivity above 10 keV



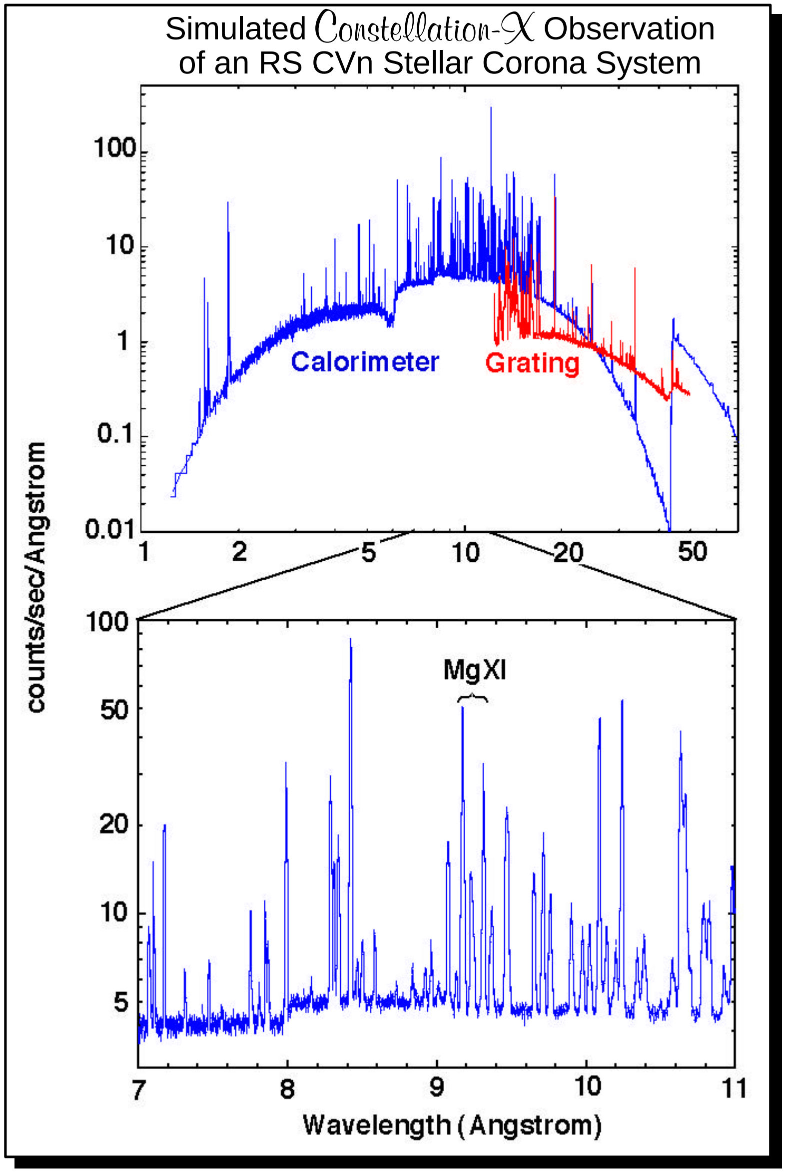
AGN viewed edge-on through the molecular torus



AGN viewed face-on

- **No previous instrument has employed focusing in the Hard X-ray band**
- **Multilayer coatings and hard X-ray pixelated detectors to increase high energy response**
- **Dramatic sensitivity improvements will be achieved**

Abundance Determinations with the Constellation X-ray Mission



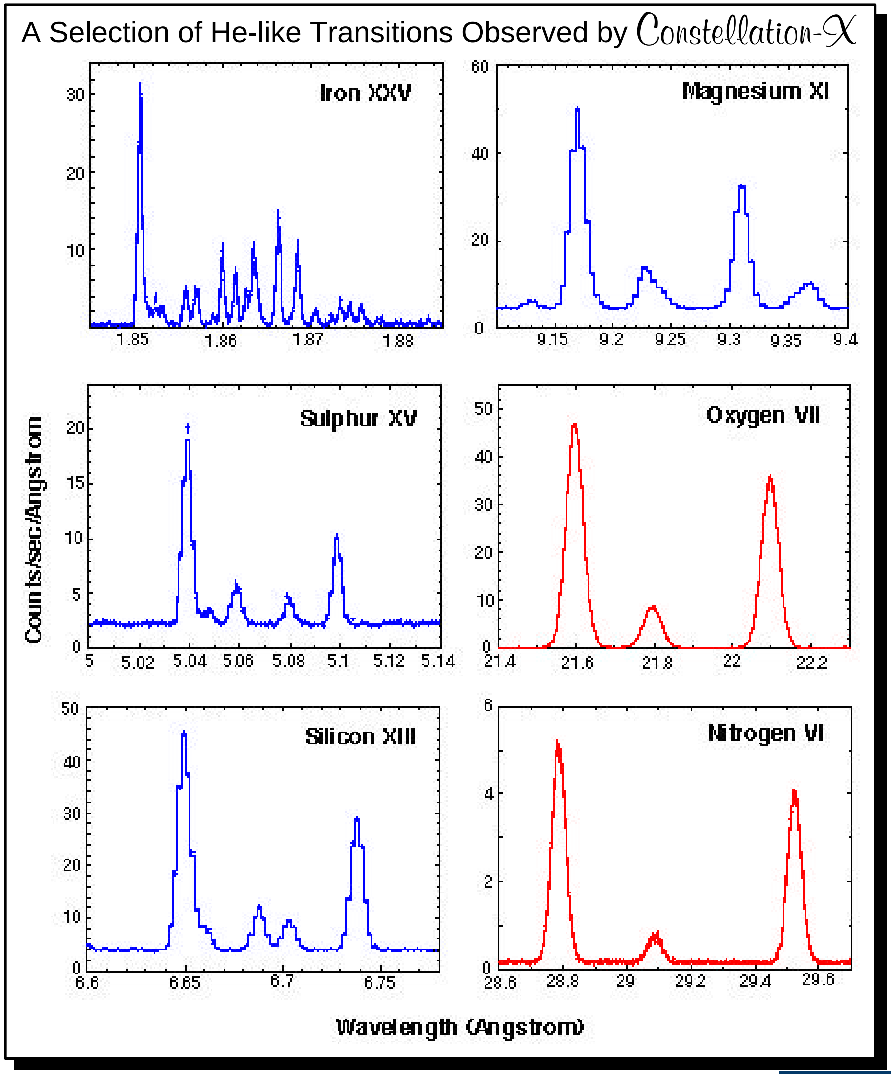
The Constellation-X energy band contains the K-line transitions of 25 elements allowing simultaneous direct abundance determinations using line-to-continuum ratios

The sensitivity of Constellation-X will allow abundance measurements in:

- the intracluster medium in distant clusters,
- the halos of elliptical galaxies,
- starburst galaxies,
- stellar coronae,
- young and pre-main sequence stars,
- X-ray irradiated accretion flows, and
- supernova remnants and the interstellar medium.

Temperature, Density, and Velocity Diagnostics

The spectral resolution of the Constellation X-ray Mission is tuned to study the He-like density sensitive transitions of Carbon through Zinc



Direct determination of

- densities from 10^8 to 10^{14} cm^{-3}
- temperature from 1-100 million degrees.

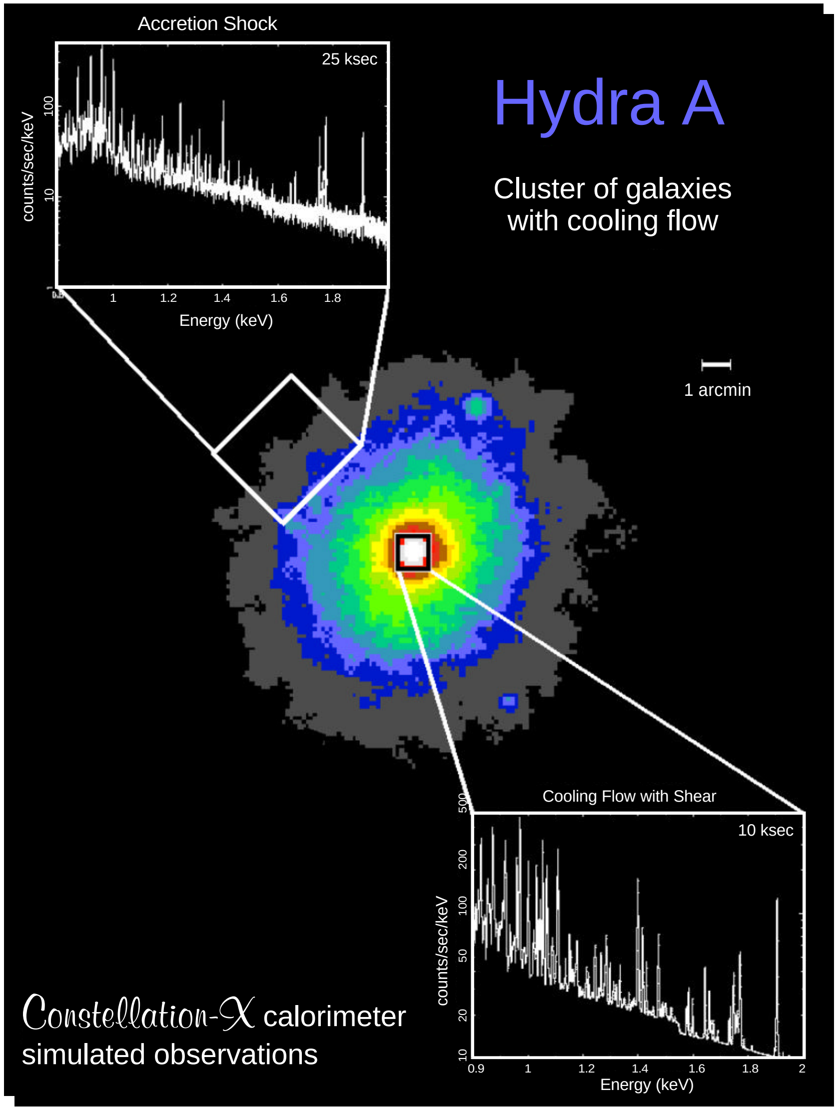
Velocity diagnostics at Fe K line:

- line width gives a bulk velocity of 100 km/s
- line energy gives an absolute velocity determination to 10 km/s

Simultaneous determination of the continuum parameters

Observations of Clusters of Galaxies

Baryon content of Universe is dominated by hot X-ray emitting plasma

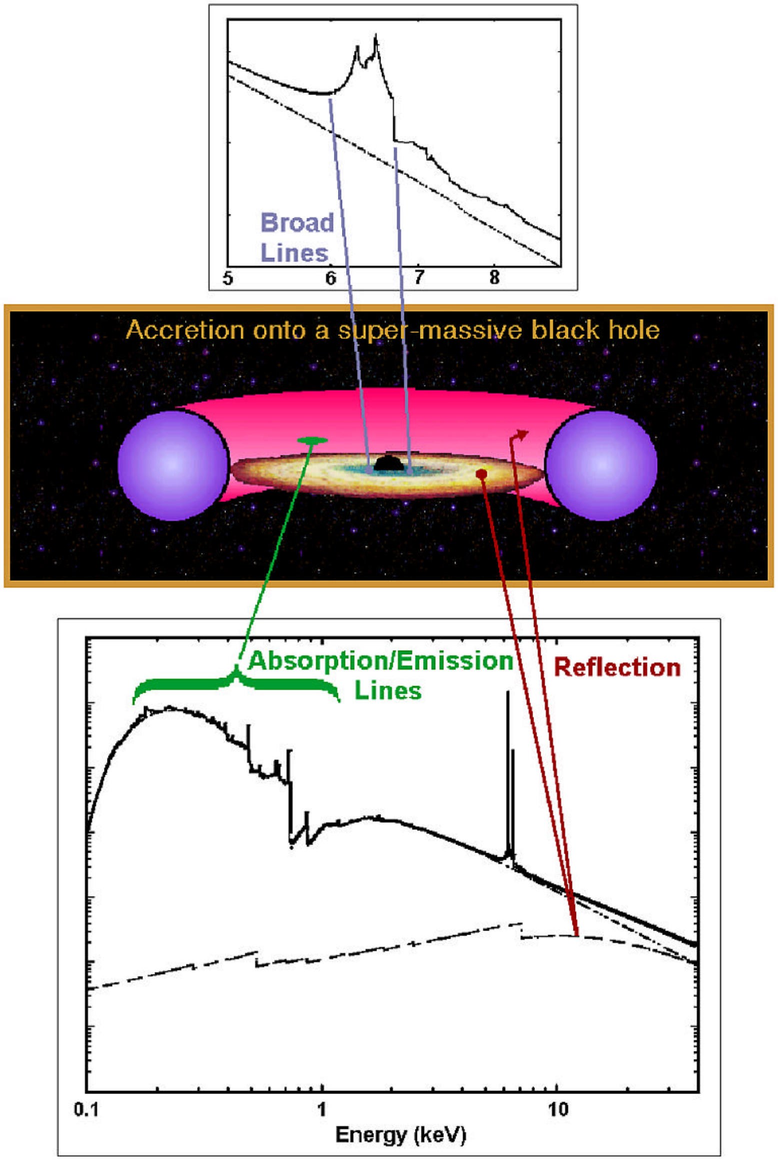


Clusters of galaxies are the largest and most massive objects known

Constellation-X observations of clusters essential for understanding structure, evolution, and mass content of the Universe

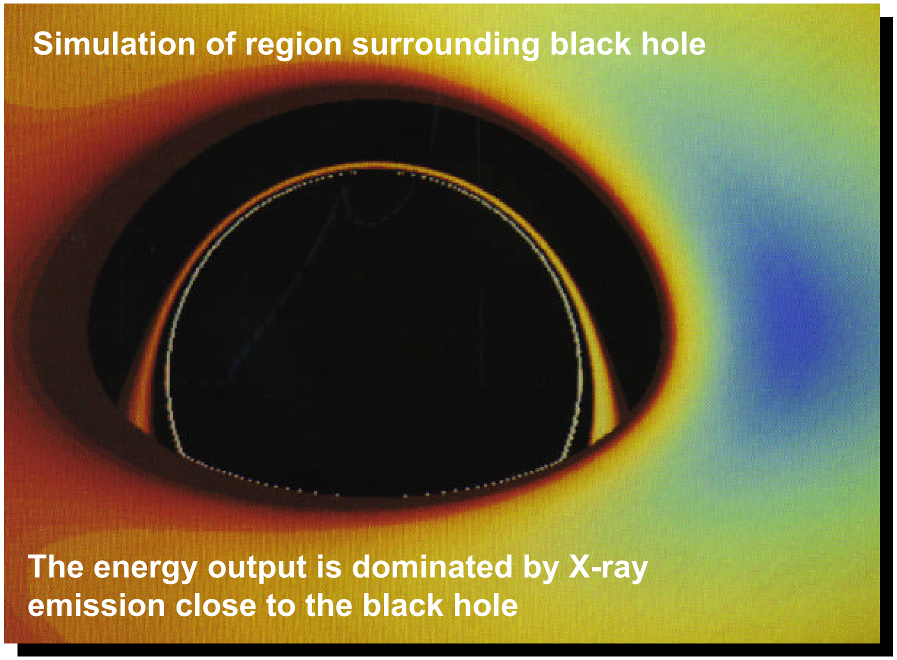
- Observe epoch of cluster formation and determine changes in luminosity, shape, and size vs redshift
- Measure abundances of elements from carbon to zinc, globally mapping generation and dissemination of seeds for earth-like planets and life itself
- Map velocity profiles, probing dynamics and measuring distributions of luminous and dark matter

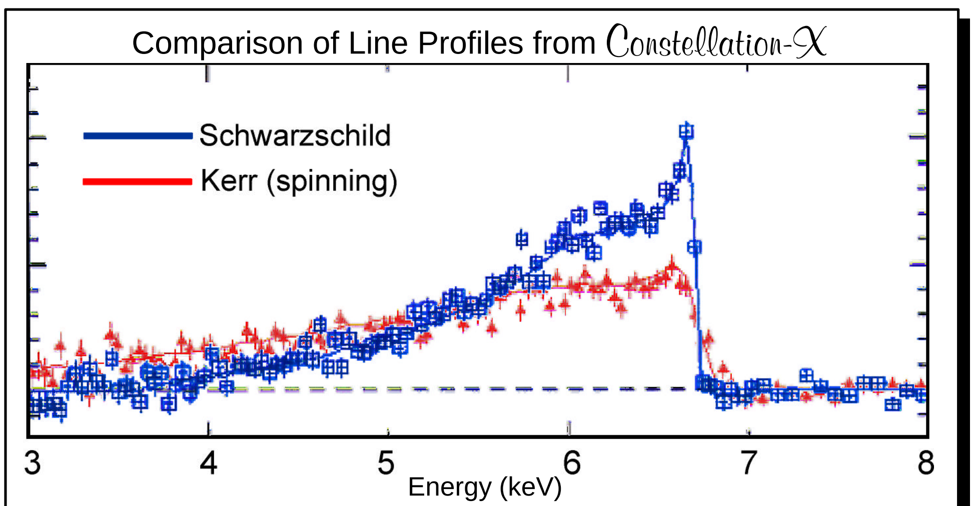
Observations of Supermassive Black Holes with the Constellation X-ray Mission



- Obtain the first detailed X-ray spectra of AGN out to redshift 5
- Study the faint AGN populations
- Resolve narrow X-ray emission line components in the spectra of AGN
- Test general relativity in the strong gravity limit.
- Determine the rotation rate and mass of black holes
- Determine the geometry of the accretion flow

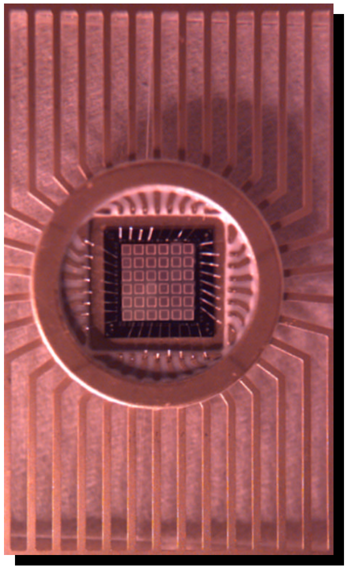
Constellation-X Will Determine the Nature of Supermassive Black Holes



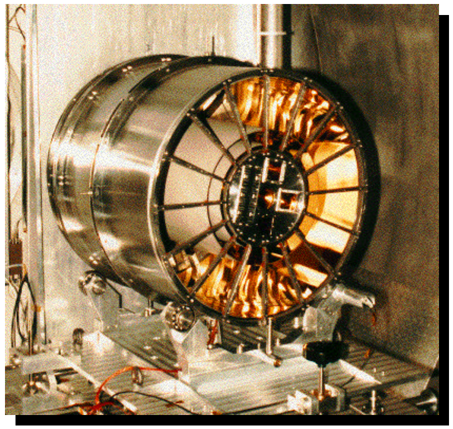


- Active galactic nuclei and quasars powered by accretion of matter onto supermassive black holes
- X-rays produced near event horizon and probe 100,000 times closer to black hole than HST
- Relativistically broadened iron lines probe inner sanctum near black holes, testing GR in strong gravity limit
- **Constellation-X will determine black hole mass and spin using iron K line**
  - Spin from line profiles
  - Mass from time-linked intensity changes for line and continuum

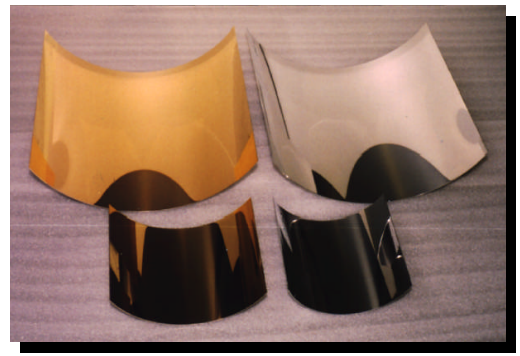
Constellation-X Technology Requirements



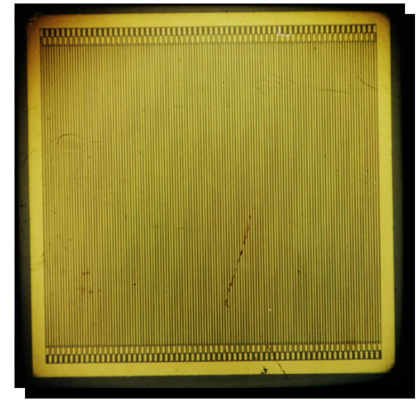
Microcalorimeters



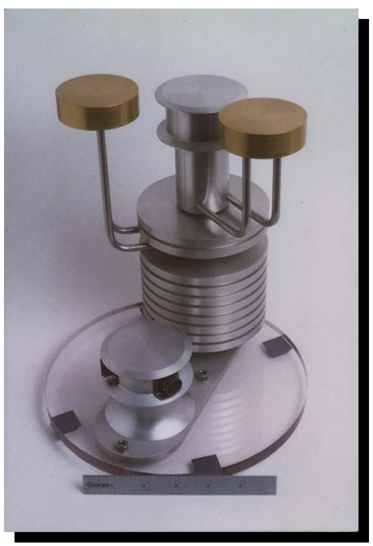
Lightweight
X-ray Optics



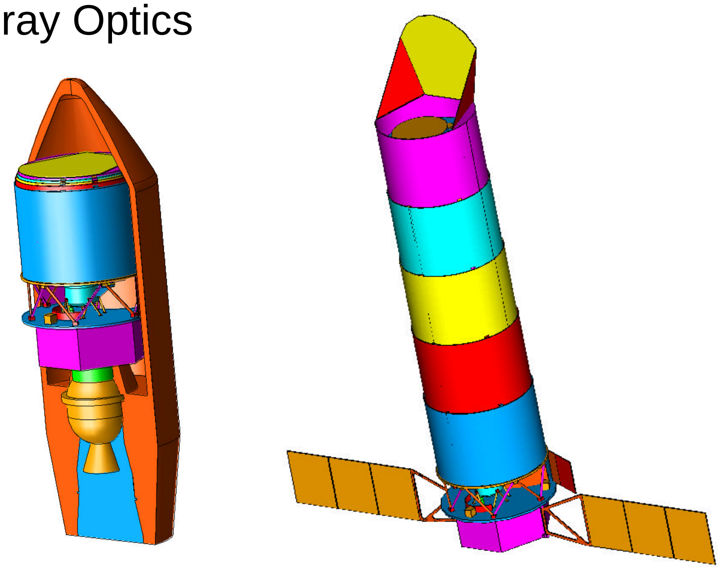
Multilayer Coatings



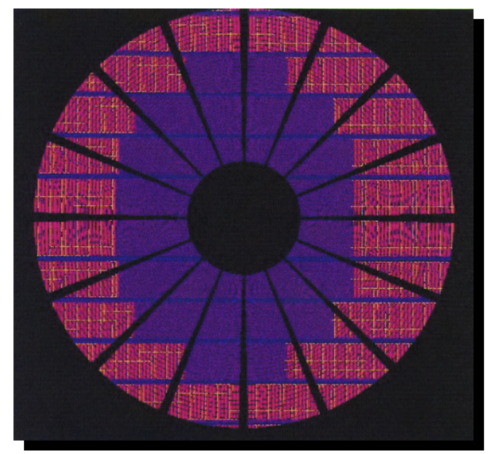
CdZnTe Arrays



Coolers



Deployable Structures



CCD/Grating

X-ray Observatories Timeline

Constellation-X

Upcoming Missions:

- AXAF
- Spectrum XG
- XMM
- Astro-E

Current Missions:

- ROSAT
- ASCA
- RXTE
- BeppoSAX

1996 1998 2000 2002 2004 2006 2008 2010

Constellation-X Key Events Over Past Year

Feb 1997 - Issued ***The High Throughput X-ray Spectroscopy (HTXS) Mission***

The Technology Roadmap

Mar 1997 - Independent Review and SEUS endorsement for HTXS Mission

May 1997 - Breckenridge SScAC meeting approves HTXS as candidate FY04 new start

- Jean Grady appointed Study/Program Manager

Jun 1997 - Second presentation to NASA Administrator Dan Goldin

Jul 1997 - State of the Universe report to Wes Huntress

Aug 1997 - Presentation at IAU Meeting in Kyoto

Sep 1997 - Letter to HT and NW from Alan Bunner requesting formation of Facility Science Team

- Visit Europe to discuss with ESA cooperation in technology development

Oct 1997 - Name changed to Constellation-X

Constellation-X Key Events Over Past Year

Nov 1997 - **HEAD** Meeting exhibit

Dec 1997 - Letter from Alan Bunner inviting scientists to join C-X FST

- ESA declines to cooperate (for time being)

- Wes Huntress approves release of FY98 funding (~$3.2M) for C-X technology program

Jan 1998 - AAS Meeting exhibit

Feb 1998 - President's FY99 budget request includes funding for C-X technology for FY99-03 (but less than required)

- Release of NRA for funding instrument technology development

- Initial meeting of C-X FST

Mar 1998 - Release of CAN for funding industry participation in mission architecture studies

Constellation-X Technology Roadmap
Hard X-ray Telescope: Optics

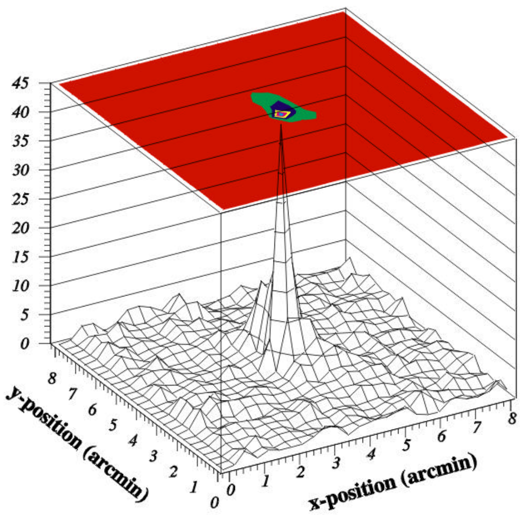
<u>Primary Approach - Segmented shells</u>

- **Approach drawn from *ASCA, ASTRO-E, SODART***
- **Epoxy replicated foils or thermally-formed glass substrates:**
    - Mass ~ 100 kg achievable
    - Measured surface quality - 3.7 Å glass, 5.5 Å foils meets requirements

<u>Required technical development</u>

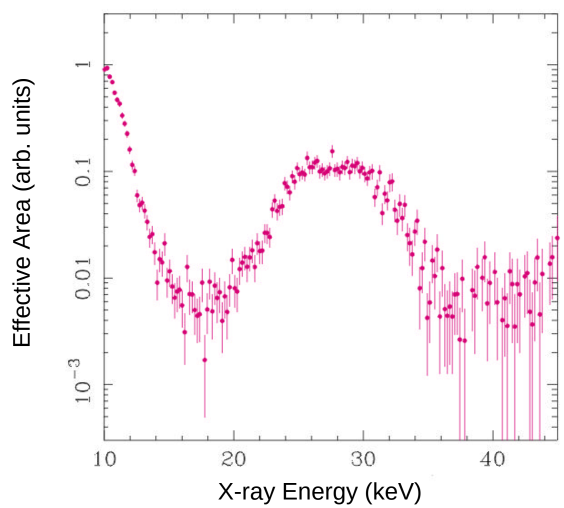
- **Demonstrate coating without distortion**

Pt/C Foil Optic and
CdZnTe Strip Detector Mosaic (20-40 keV)



GSFC/Nagoya

Effective Area

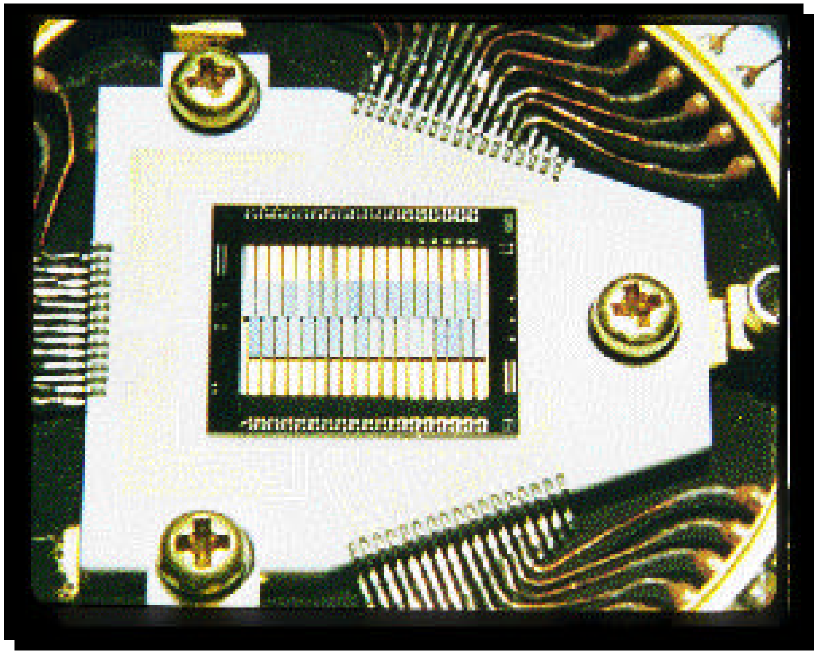


- Image at 30 keV achieved in August 1997 using Pt/C multilayer on an epoxy replicated foil mirror shell at GSFC/Nagoya -- 30 layer pairs, 0.13 micron thick with no distortion of foil due to stress

- W/Si multilayer on curved glass at Caltech/Columbia -- 200 layer pairs, 0.66 micron thick with acceptable stress

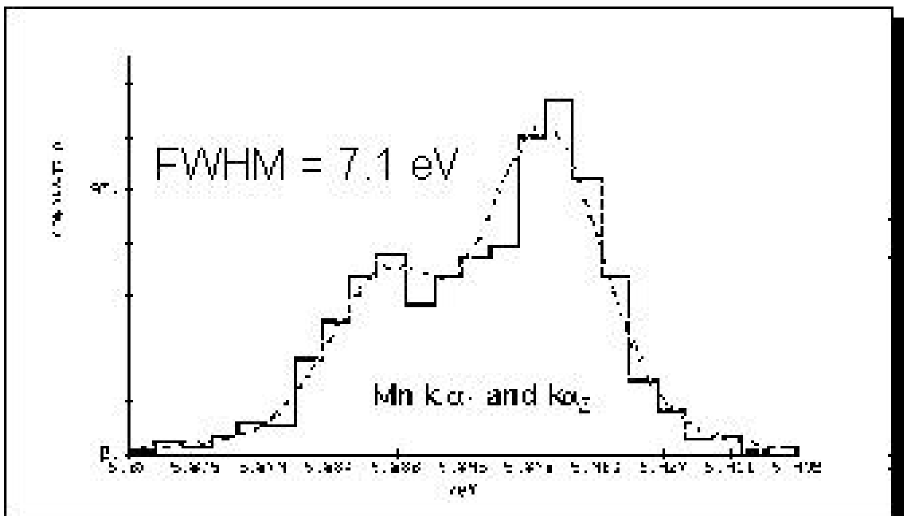
- Balloon flights planned in 1999

Constellation-X Calorimeter Advances



First flight test of Microcalorimeter

- Wisconsin/GSFC rocket flight 06/96
- 36 pixel array operating at 60 mK
- Observation of diffuse X-ray background
- Resolution of 14 eV at 277 eV achieved
- Detection of Sulfur IX and Oxygen VII
- Next flight 8/97 with improved array



First demonstration of TES Calorimeter at NIST

- Transition Edge Superconduction thermometer
- First result of 7.1 eV in Summer 1996 matches best to date
  - Capable of higher energy resolution
  - Higher counting rates
  - Lower cryogenic heat loads
- Not yet optimized!
  - expect significant improvement

Constellation-X Organization

Project Formulation Manager
Jean Grady

Facility Science Team
Chair: Harvey Tananbaum

Project Scientist
Nicholas White

Systems Engineers
William Prodgorsky
Mike Weiss

Mission Scientists
Frank Marshall
Jay Bookbinder

Technology Development

Spectroscopy X-ray Telescope
Leon Van Speybroeck

X-ray Calorimeter
TBD

Hard X-ray Telescope
TBD

CCD/Grating
TBD

Cooler
S. Castles

Extendible Optical Bench
Oren Sheinman

Mission Study

C&DH
Phil Luers

Mechanical
Oren Sheinman

Launch

ACS
Alan Reth

Flight Dynamics
Greg Marr

Ground Segment
Gary Meyers

Constellation-X Goals for the Coming Year

- Make significant progress in technology
  - initiate technology development programs
  - incorporate results of industry and GSFC/SAO mission study activities

- Target the upcoming decadal committee report
  - make a concise science case (for multiple audiences)
  - highlight the public appeal of C-X science
  - public brochures, posters, and other PR handout materials

- Address funding issues
  - technology development budget (FY98-01) currently ~1/2 requested/required per Technology Roadmap (FY98-00)
  - funding for Phase A and B not covered in current budget request
  - identify savings in end-to-end costs (1997-2012)

- Support upcoming events
  - 1998 State of the Universe report to Wes Huntress (or replacement) in May
  - SEU special session at San Diego AAS Meeting
  - C-X display at January AAS Meeting